SITE CHARACTERIZATION FOR CO_2 GEOLOGIC STORAGE AND VICE VERSA

THE FRIO BRINE PILOT AS A CASE STUDY

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Title Interpreted

A. Site characterization for CO_2 geologic storage

B. CO_2 geologic storage as one component of site characterization

- Traditional site-characterization important, especially for saline aquifers not previously utilized for other purposes
- To understand sequestered CO_2 behavior in subsurface, no substitute for studying movement of CO_2 directly
  - Two-phase flow properties
  - Flow behavior that depends on density and viscosity

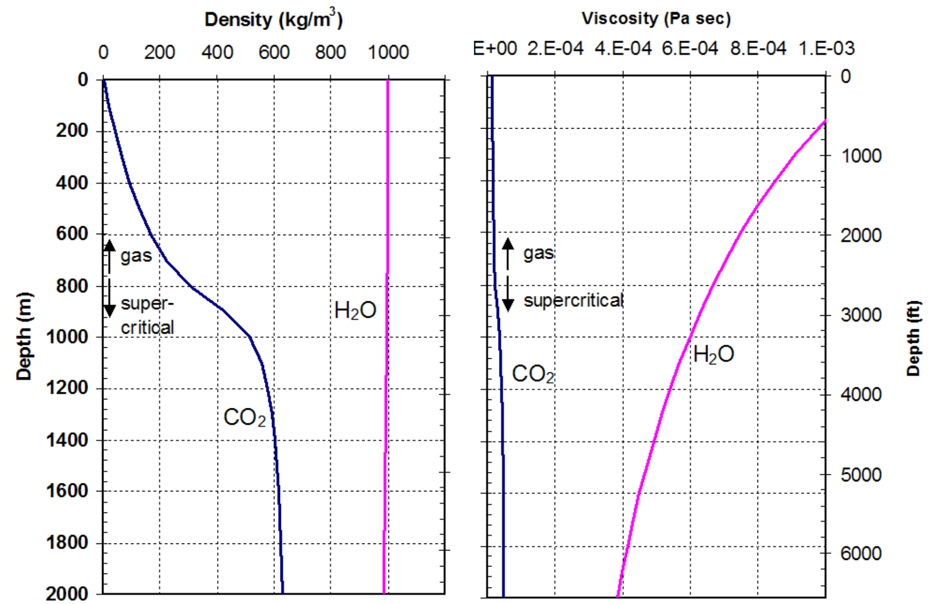
→ Integrated, iterated approach: A B A B A

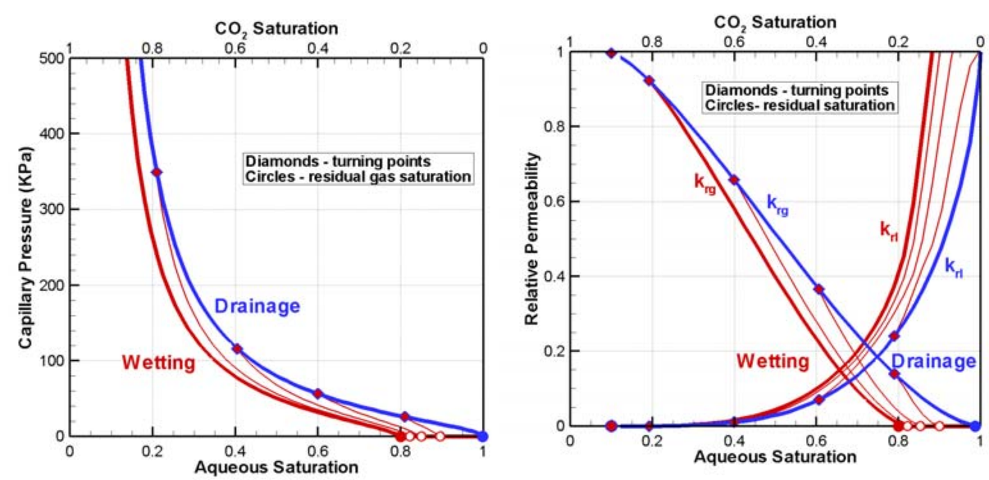
Outline

- Subsurface flow and transport processes involved in geologic sequestration
- Site-characterization methods
- The Frio brine pilot
- Conclusions

Subsurface Flow and Transport Processes

1. Put a large quantity of CO_2 into the subsurface
   - Injectivity: permeability
   - Storage capacity: porosity
   - Storage efficiency: depth
2. Make sure it stays there for a long time
   - Stratigraphic trapping
   - Mobility trapping
   - Solubility trapping
   - Chemical trapping





CO_2 injection - drainage: controlled by S_{lr}
Post-injection - wetting: controlled by S_{gr}

Subsurface Flow and Transport Processes — Site-characterization methods

1. Put a large quantity of CO_2 into the subsurface
   - Injectivity: permeability — well logs*, core analyses, pump tests*
   - Storage capacity: porosity — well logs*, core analyses, tracer tests*
   - Storage efficiency: depth
2. Make sure it stays there for a long time
   - Stratigraphic trapping — regional geology, geophysical imaging*, well logs*
   - Mobility trapping — multi-phase flow behavior of brine/CO_2 systems** (or oil/gas)
   - Solubility trapping — fluid samples, regional flow*
   - Chemical trapping — core samples, fluid samples

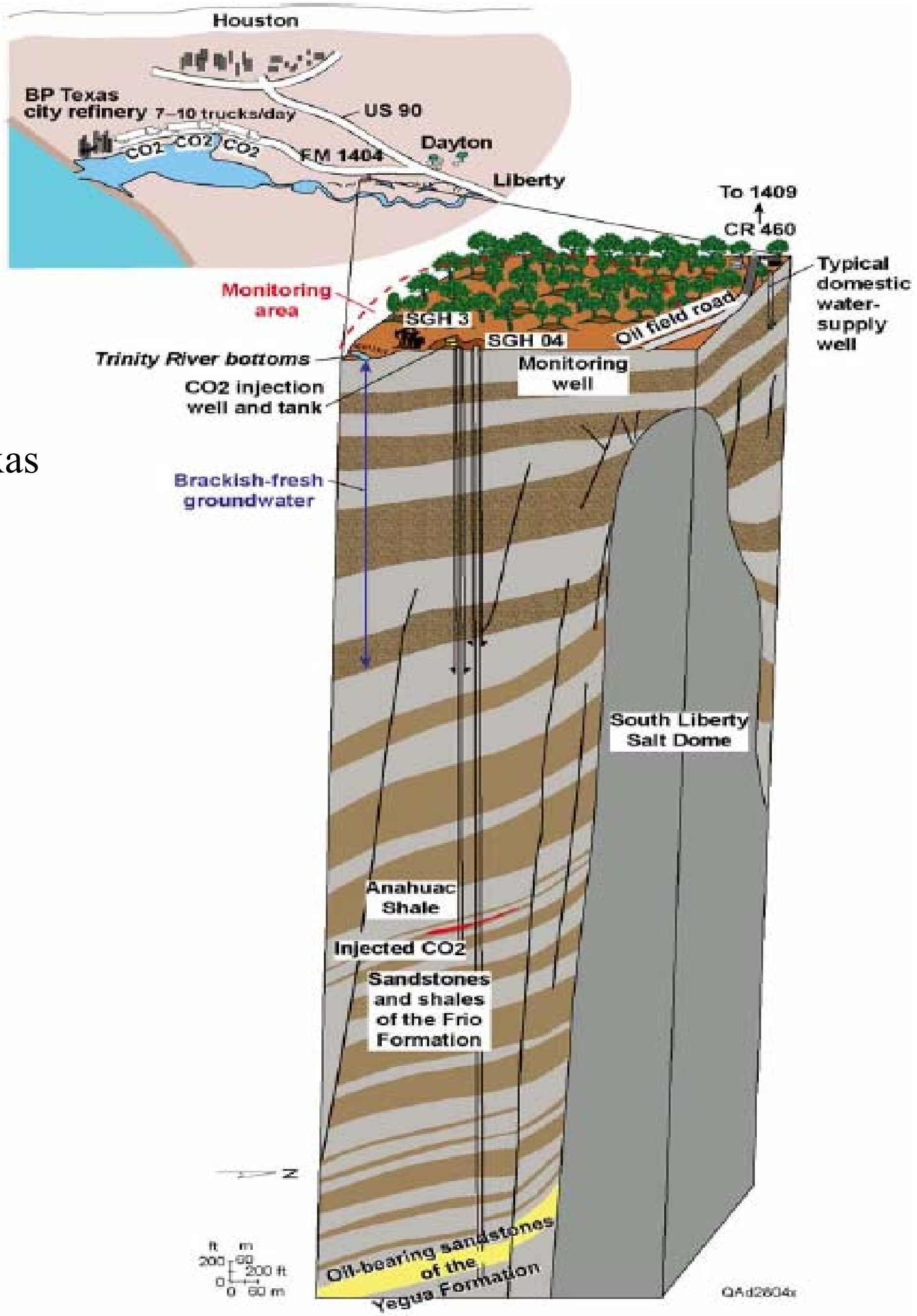
Numerical Modeling Concurrent with Site Characterization

- Design tests
- Predict test outcomes to assess the current state of knowledge
- Compare model results to field observations
  - calibrate unknown parameters
  - incorporate new features

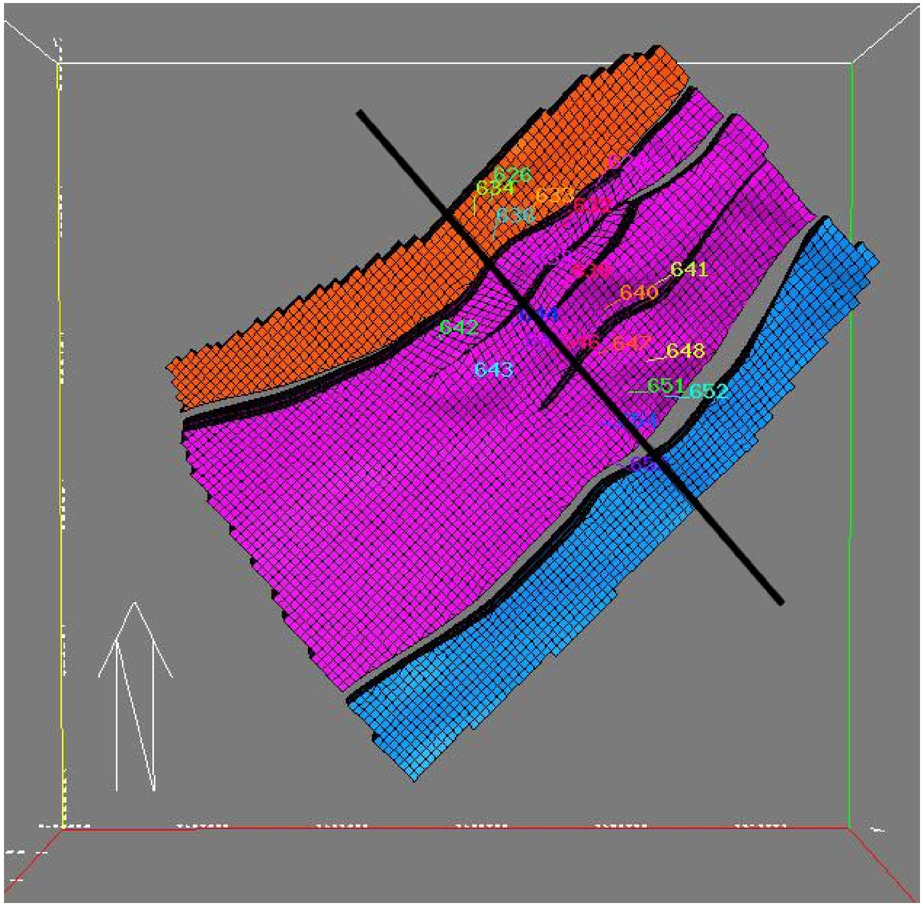
Frio Brine Pilot

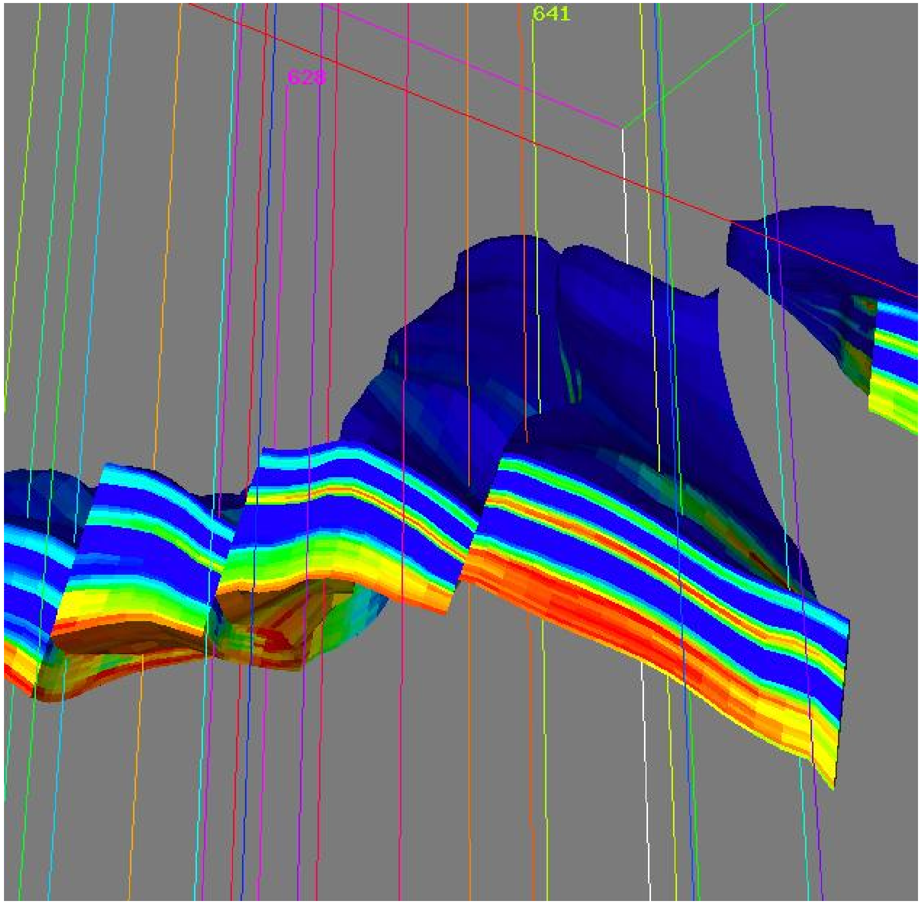
BEG, Berkeley Lab, USGS, Livermore, Oak Ridge, Alberta Research Council, Schlumberger

- Frio formation
  - High porosity and permeability
  - Widely distributed over Upper Texas Gulf Coast
- South Liberty Field
  - Flank of salt dome
  - Fault-block compartmentalization
  - Historical oil production
- C sand (brine, no hydrocarbon)
  - 1500 m depth, 23 m thick, 17^o dip
  - P = 150 bars, T = 55^{o}C
- Two wells
  - 30 m separation
  - Injection well downdip
  - Wells perforated over upper 6 m
- 1600 metric tons of CO_2
- 10-day injection period



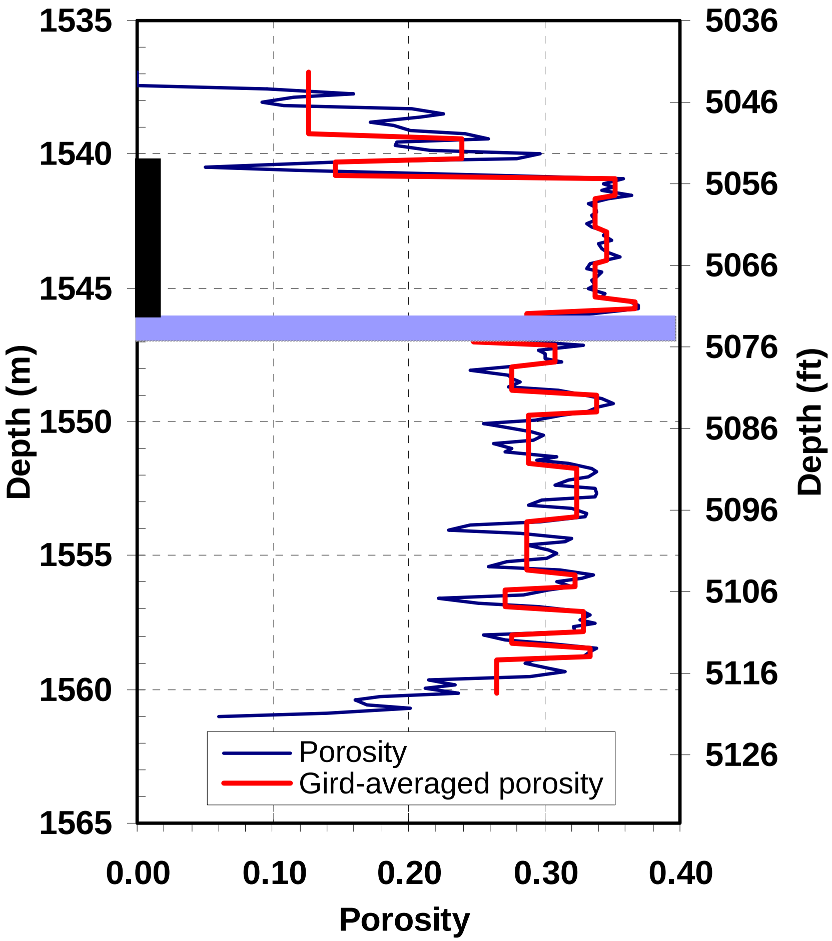
Structural Setting
(3D Seismic, many well logs)

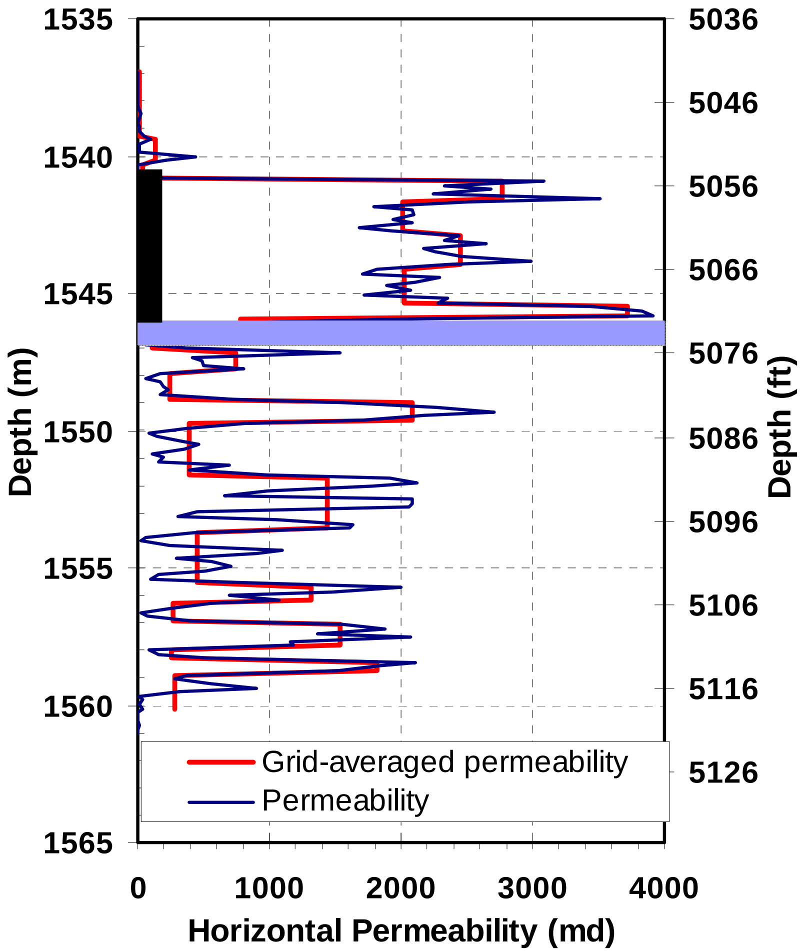




Well Logs

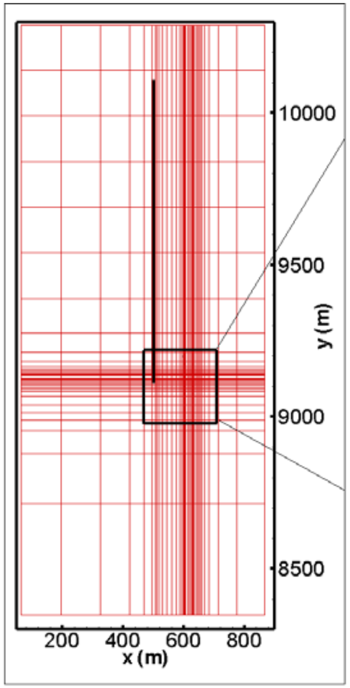
(from new injection well; consistent with other local wells)

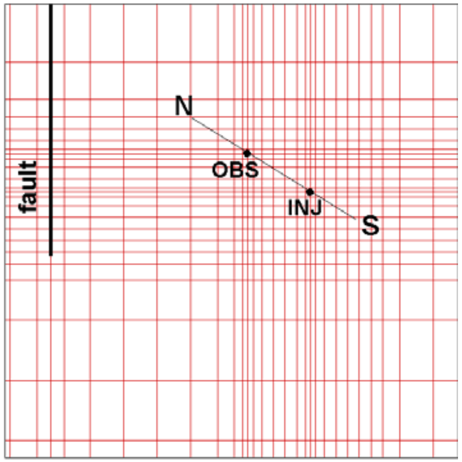


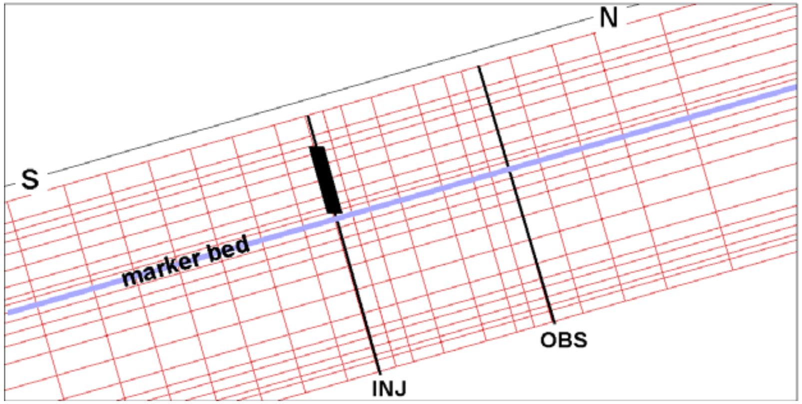


Features of Numerical Model

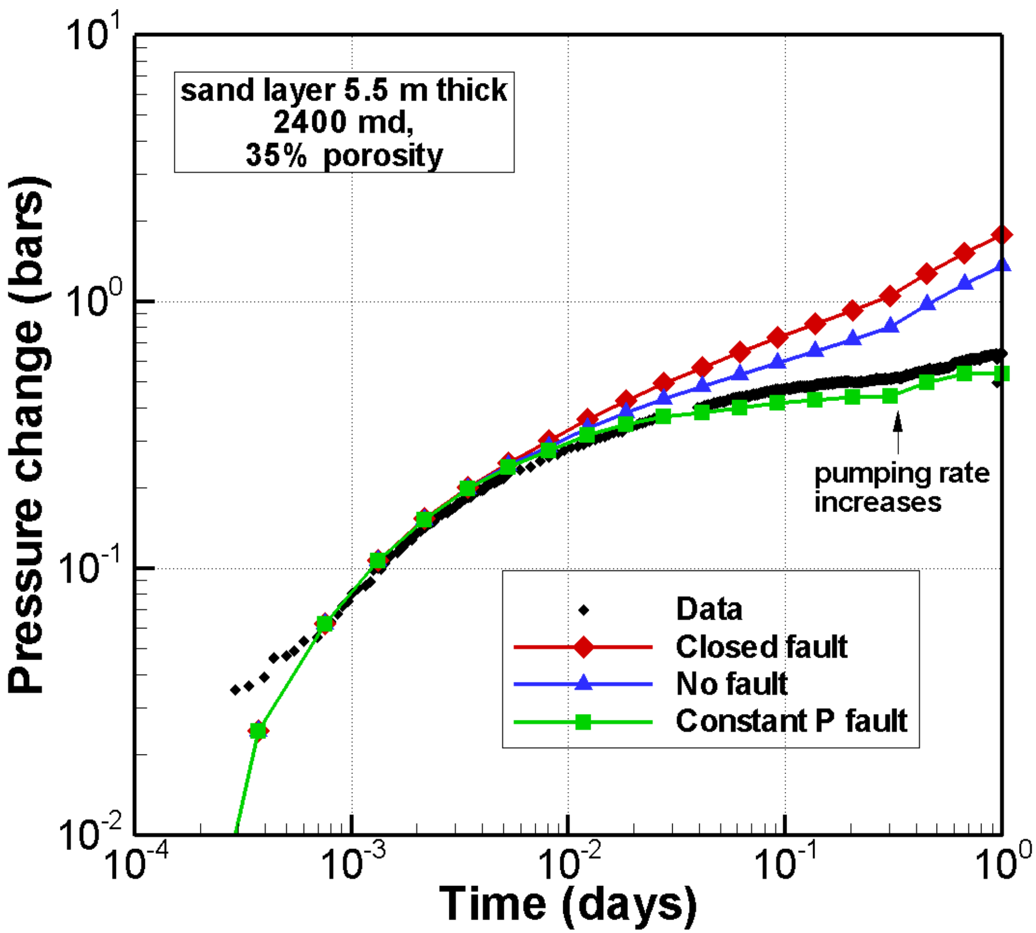
- Numerical model TOUGH2, multi-phase, multi-component simulator
  - CO_2: supercritical, dissolved
  - H_2O: aqueous, gas
  - NaCl: dissolved, precipitated
- 3D grid, finer near wells
- Tilted plane to represent average dip of 16°
- Hysteretic characteristic curves
  - CO_2 Injection: drainage, controlled by S_{lr}, S_{gr}~0
  - Post-injection: wetting, controlled by S_{gr}





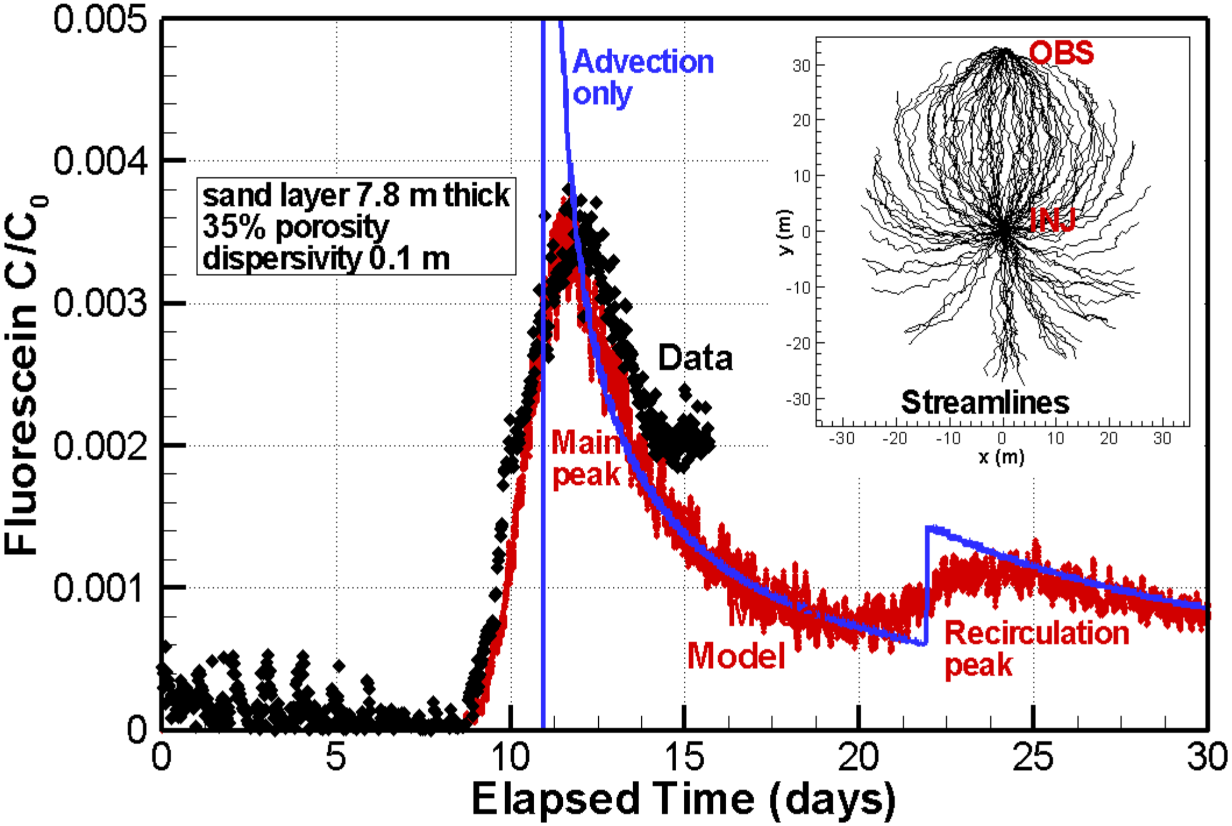


Single-Phase Well Test



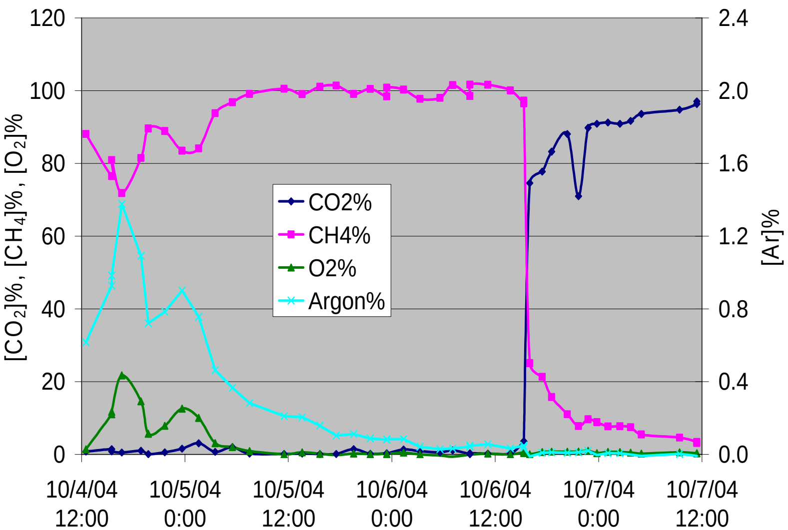
- Well-test analysis yields permeability consistent with core sample measurements
- Late-time behavior suggests faults are not closed boundaries
- Maximum pressure increases useful for equipment design and regulatory compliance

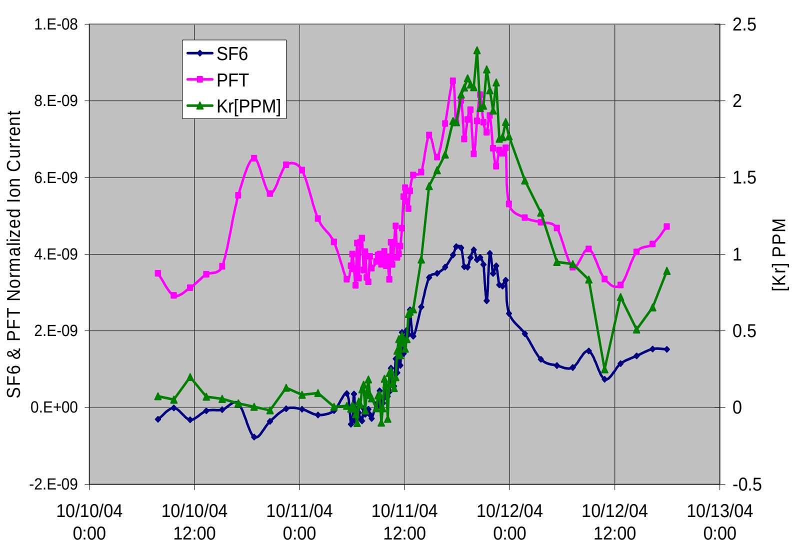
Single-Phase Tracer Test

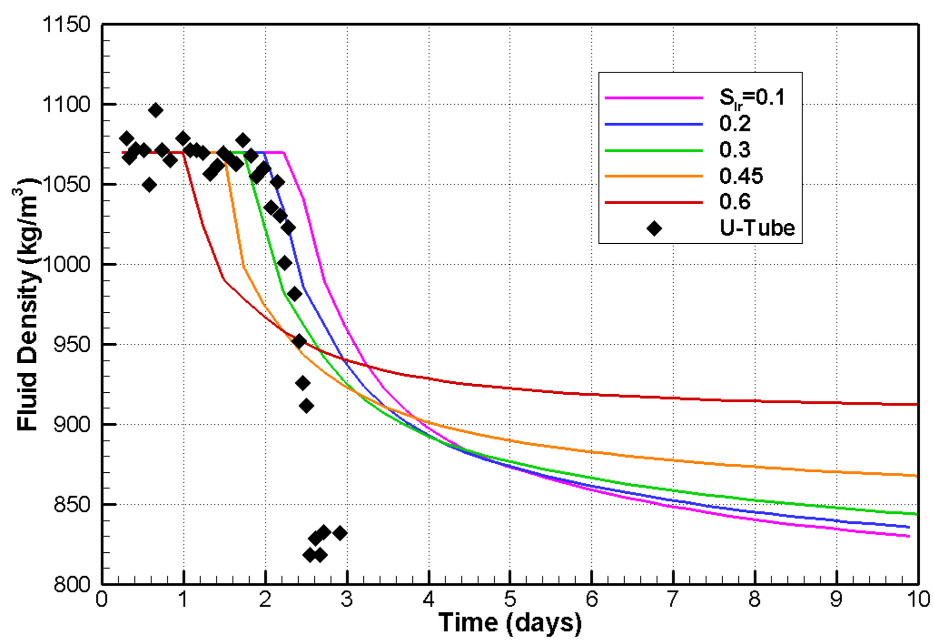


- Streamline model with random walk to represent dispersion
- Fit to observed Fluorescein BTC yields
  - Small dispersivity
  - Large porosity-thickness product
- Infer sand layer thickens between wells

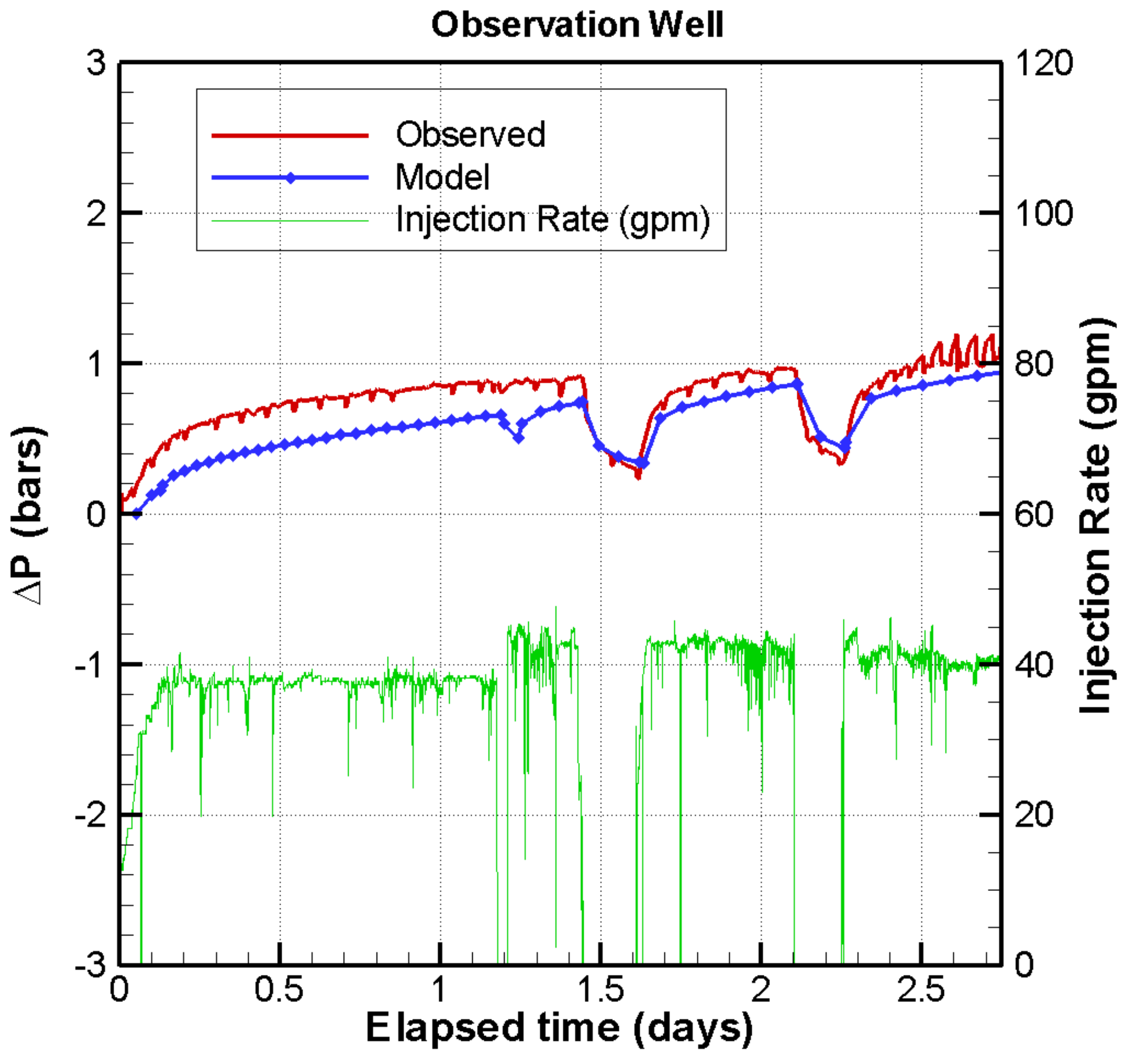
CO_2 and Tracer Arrival at Observation Well



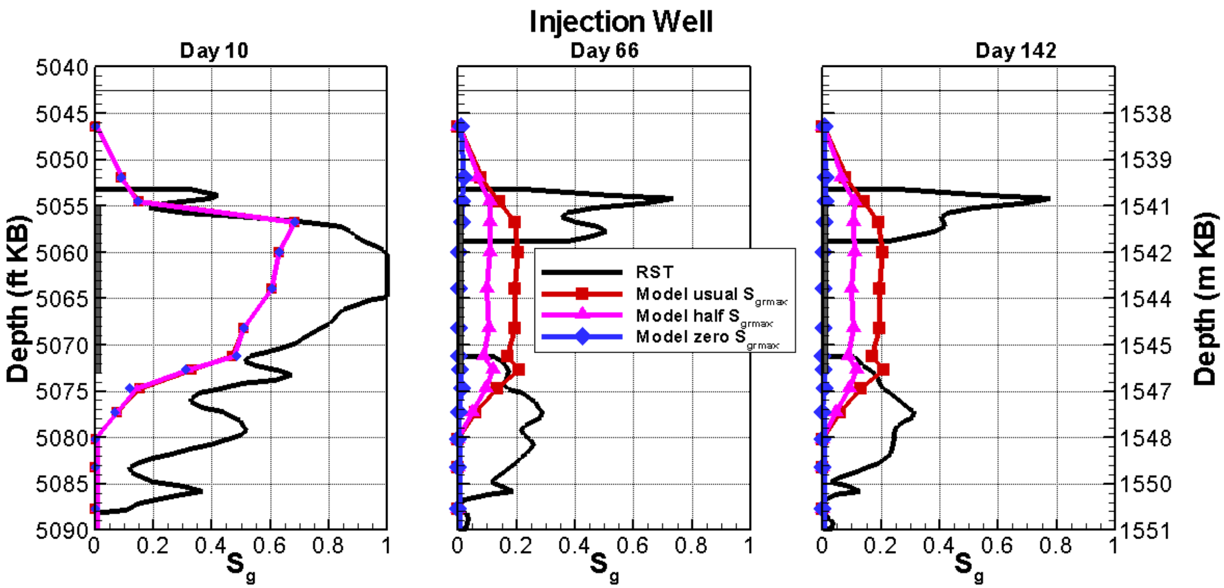




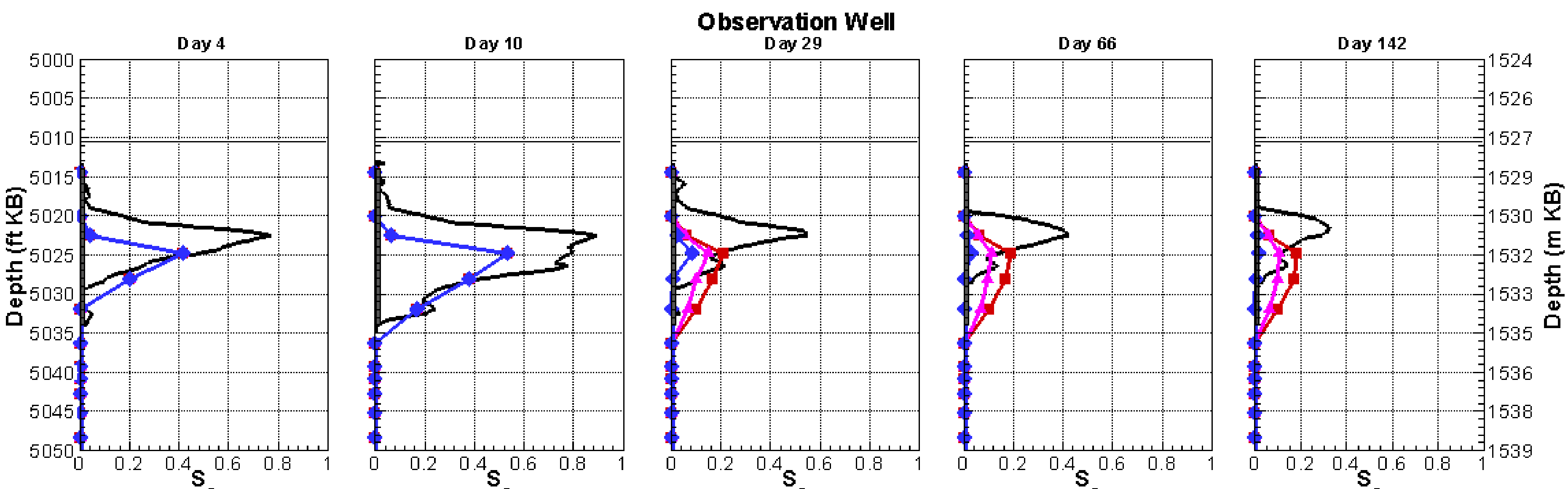
CO_2 Pressure-Transient Analysis



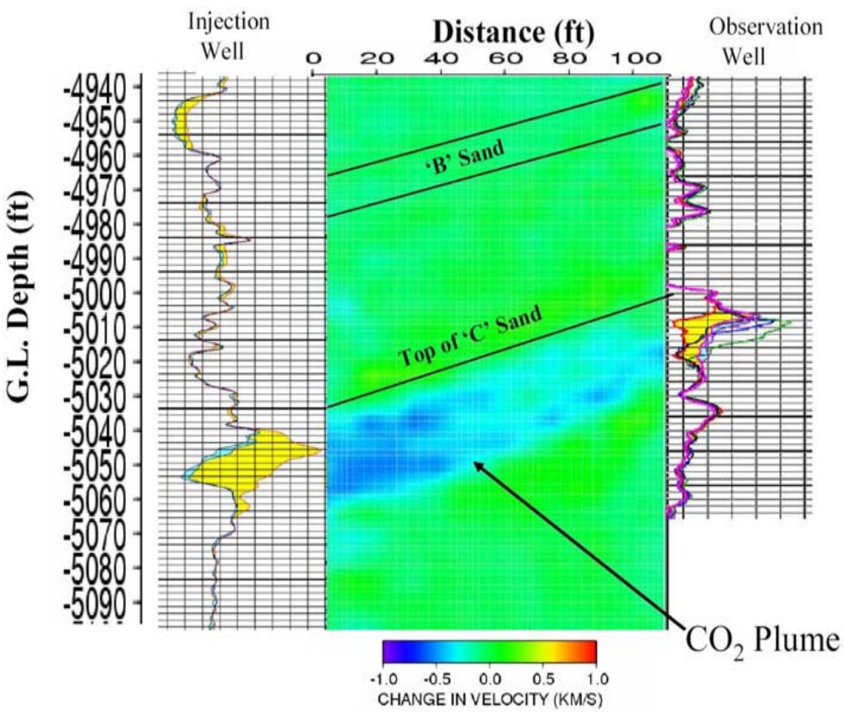
Reservoir Simulation Tool

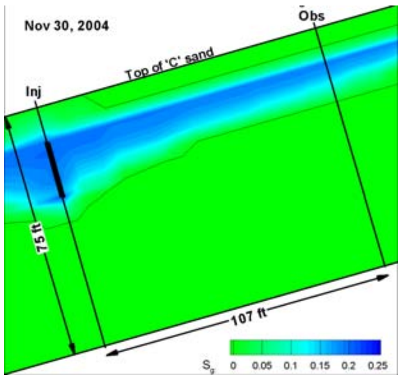


- Magnitude constrains characteristic curves
- Depth: details of geology
  - –Marker bed below perforations non-sealing
  - –Discontinuous caprock

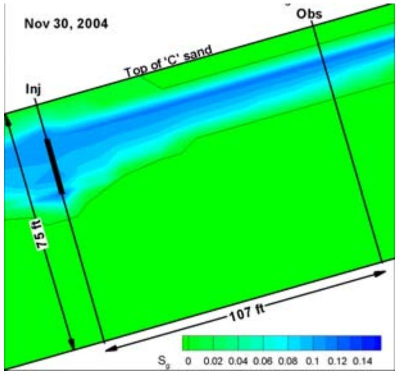


Cross-well Seismic Tomography

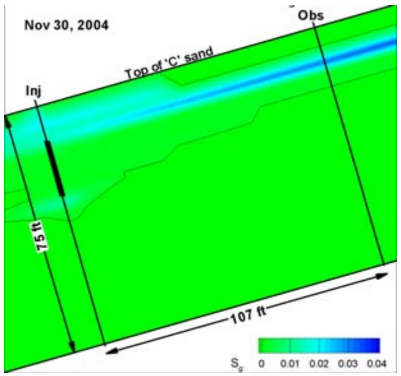




Usual S_{grmax}



Half S_{grmax}

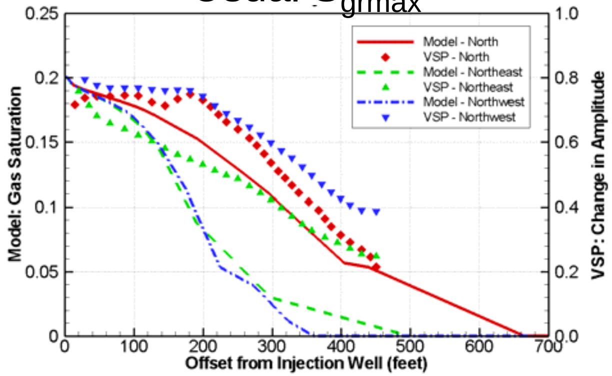


Zero S_{grmax}

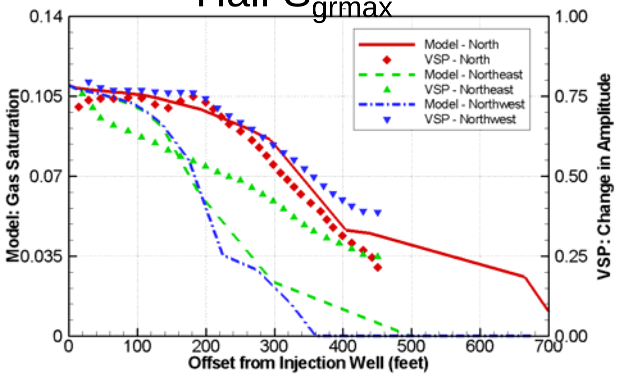
- Image CO_2 distribution in plane between wells two months after injection
- Suggests heterogeneity in permeability distribution

Vertical Seismic Profile

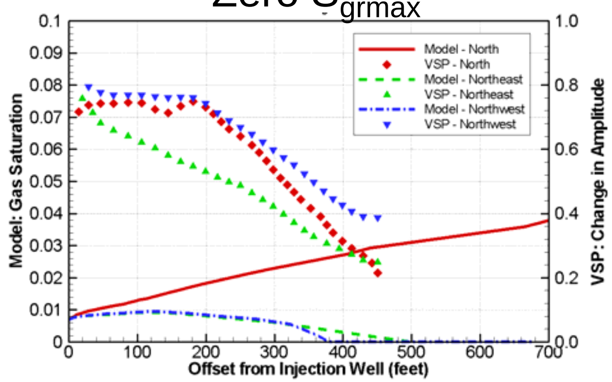
Usual S_{grmax}



Half S_{grmax}



Zero S_{grmax}



- Explosions at surface, monitor downhole, along three azimuths: N (updip), NW, and NE
- Estimate extent of CO_2 beyond wells about two months after injection
- Comparison with model suggests
  - True updip direction may not be N
  - $S_{grmax} \sim 0.2$

Advantages of Integrated Approach

- Multi-phase flow properties
- Low density and viscosity of CO_2 compared to brine
  - Distinct flow paths
  - Distinct features_of the geology

- To understand sequestered CO_2 behavior in the subsurface, there is no substitute for studying the movement of CO_2 directly

- Practical benefits
  - Surface handling of CO_2 (compression, heating, local storage)
  - CO_2 injection process
  - Monitoring techniques